The Veliger 48(2):61–74 (June 30, 2006)

THE VELIGER

A Preliminary Study on the Biology of the Predatory Terrestrial Mollusk *Rathouisia leonina*

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Abstract. A study about the natural history of the slug *Rathouisia leonina* Heude, 1882 was carried out both in the field and in the laboratory. The external morphology, distribution, habitat, food range and preference, predatory behavior and reproduction were studied. Adult slugs were up to 1.02 g in weight and 35 mm long when kept inactive. They always preyed upon eggs, juveniles and adults of snails, rather than those of slugs of other families. Smaller individuals (0.18–0.55 g) showed preferences for feeding on bradybaenid snails *Trichobradybaena submissa* with larger diameter and larger apertural opening, while larger slugs (0.63–1.02 g) showed no such preference. The slugs also showed a preference for the eggs of *Acusta ravida* over those of *Bradybaena similaris* and *T. submissa*. The length of feeding scars on snail eggs made by infant slugs measured 0.24–0.47 mm, and those made by adult slugs 0.41–0.62 mm. After copulation adult slugs laid 10–49 eggs per clutch. The number of eggs was not correlated with their parent slugs' weight but the diameter of the eggs (1.88–3.09 mm) showed a positive correlation to the parent slugs' weight. It took 25–29 days for the eggs to hatch at 17.5–23.5°C, 86% ± 5% RH in the laboratory.

INTRODUCTION

Rathouisia leonina Heude, 1882 (Heude abbreviated as H. below) is a mollusk species that has not received attention since its original description. Among the approximately two thousand known species of land- and freshwater gastropods in China, rathouisiid slugs have received little attention. Soleolifera (*sensu* Solem, 1978) comprise two families: Rathouisiidae and Veronicellidae (= Vaginulidae). Along with these two terrestrial families, there is a marine family Onchidiidae (order Onchidiacea, *sensu* Solem, 1978) arranged in the superorder Systellommatophora Pilsbry, 1948. In China, six veronicellid species and three rathouisiids have been recognized: *Vaginulus carbonaria* H., 1882, *V. fargesiana* H., 1882, *V. chinensis* (Möllendorff, 1881), *V. lemonieriana* H., 1882, *V. patriatiana* H., 1882, *V. pictor* H., 1882, *Rathouisia tantherina* H., 1882, *R. tigrina* H., 1882 and *R. leonina* H., 1882 (syn. *Vaginulus sinensis* H., 1882), distributed in Sichuan, Hubei, Jiangsu, Guangdong, Guangxi, Yunnan (Wu, unpublished report) and Hong Kong. The known northernmost limit of rathouisiids in China is the northern bank of lower Yangtze River (Heude, 1882–1890).

Heude's family Rathouisiidae was based on the lack of a jaw and the presence of a protrusile proboscis or suction trunk, as well as those characters shared with the related group Veronicellidae (= Vaginulidae). The uniqueness of the mouth structure corresponds with its predatory life. There are three species belonging to the genus *Rathouisia. R. tigrina* with the smallest body size is black when alive and purple when preserved in ethanol solution; its dorsal striation is elongatedly ovate, similar to that of *R.*

Figure 1. *R. leonina.*

leonina. R. leonina lives in the limestone hills of Chengkou county (31°54′N, 108°36′E), Sichuan. *R. tantherina* lives in the same habitat as *R. tigrina,* but has a lighter body color and a longer body; its dorsal striations are polygonal to amorphous spots. *R. leonina,* studied in the present work, has a larger body size than the previous two species and its body is elongatedly cylindrical in dorsal view. *R. leonina* colonizes the eastern valley of the Yangtze River. Besides the localities mentioned below, one specimen (ZMIZ00801) collected by the Zoological Museum (Institute of Zoology, Chinese Academy of Sciences) suggests another occurrence of *R. leonina* at Shaoguan (24°48′N, 113°36′E), Guangdong, in S. China (Wu, unpublished).

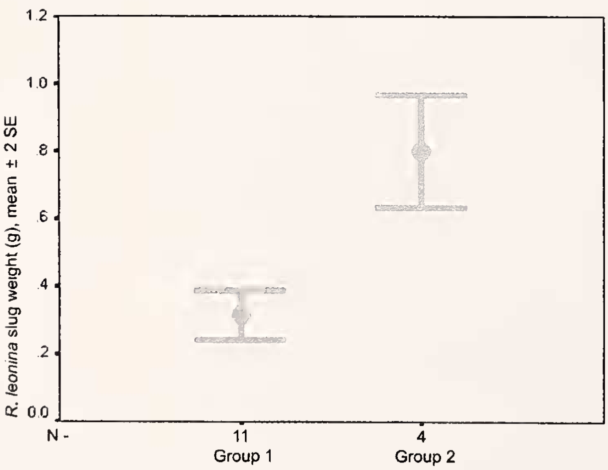

Figure 2. Mean weight ± SE (g) of *R. leonina* Group 1 and Group 2 in the experiment on prey size choice.

Heude (1882–1890) noticed that *R. leonina* is a predatory carnivore, preying upon land snails (*Helix sensu* Heude, 1882, which might belong to Bradybaenidae and families with similar shell shapes, according to the recent classification of land stylommatophoran shells). Heude also mentioned in the paper (1882–1890) that *R. leonina* lives in a similar habitat to the slug *Meghimatium bili-*

Table 1

K-means Cluster Analysis for the investigated parameters of tested *T. submissa,* showing cluster centers.

Cluster center	Height (mm)	Diameter (mm)	Ratio of height/ diameter	Apertural area (mm^2)
1	6.30	7.29	.51	10.32
2	5.40	11.48	.60	23.92
3	4.24	9.53	.55	17.33

Table 2

Preference records of the predatory slugs to different parameters of *T. submissa,* in Group 1 (slugs' weight 0.189–0.55 g) and Group 2 (slugs' weight 0.63–1.02 g). Abbreviations: J—juvenile, A—adult, H—shell height, D—shell diameter, RHD—ratio of height/diameter, Ap. A.—apertural area, Asymp. Sig.—Asymptotic significance. Asterisk "*" means statistically significant here.

	Prey maturity		Conchological parameters of preys											
Slug group	J	A	H1	H2	H3	D1	D2	D3	RHD 1	RHD 2	RHD 3	Ap. A. 1	Ap. A. 2	Ap. A. 3
Group 1														
Sum of records	6	16	10	10	2	2	11	9	8	4	10	2	9	11
Asymp. Sig.	0.033*			0.055			0.048*			0.280			0.048*	
Group 2														
Sum of records	5	3	3	1	4	3	3	2	3	2	3	2	3	3
Asymp. Sig.	0.480			0.417			0.882			0.882			0.882	

neatum (Benson, 1842) (Philomycidae), although the former species is not observed commonly.

Although having a larger body size, *R. leonina* closely resembles *Incillaria* sp. (sensu Kurozumi, 1985; *Incilaria* Benson, 1842, a synonym of *Meghimatium* van Hasselt, 1823), which is distributed in Okinawa (26°13′N, 127°40′E), Japan, based on available information on morphological characters and biology (Kurozumi, 1985). Interestingly, *R. leonina* attacked all snails tested in the present work only through the shell aperture rather than both in this manner and drilling into the snails' shells, reported for *Incillaria* sp. (sensu Kurozumi, 1985). None of the two reports (Heude, 1882; Kurozumi, 1985) provides a picture or photograph of such drilled shells with feeding scars, although the photograph of the scars left on the calcareous egg shells, which is quite similar to those left by *R. leonina,* were shown from *Incillaria* sp. (sensu Kurozumi, 1985). Based on this point and the morphological similarity, *Incillaria* sp. (*sensu* Kurozumi, 1985) might be more closely related to *R. leonina* than to herbivorous philomycid slugs. The eventual solution for this question will be based on the intensive comparative study of their morphology, habitats and other relevant ecological issues.

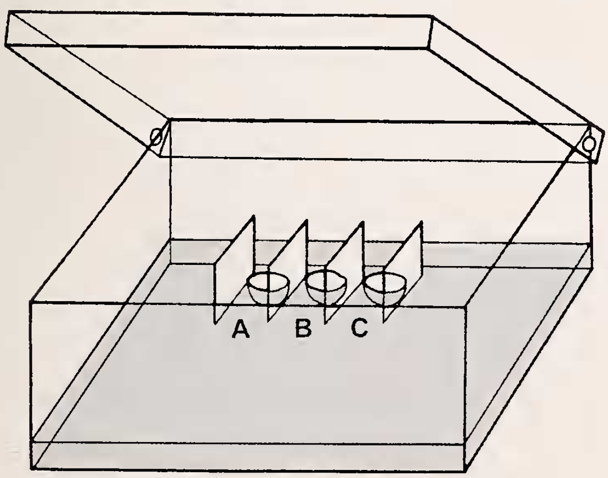

Figure 3. Experimental set used to detect the egg choice of *R. leonina.*

This paper is the preliminary part of a work dealing with several aspects of *R. leonina,* which originated from both the interest in this rarely seen predatory slug and using it as a potential bio-control agent. However, the latter idea has been postponed, because of both the lack of detailed biological data and the extremely powerful predatory capacity of this creature shown in the experiments which raised special bio-safety considerations. Other problems revealed during this work and others in progress will be discussed elsewhere.

MATERIALS AND METHODS

Field Survey

Field surveys were conducted respectively during May 2000 in Zhongshanling (32°00′N, 118°42′E), Nanjing, Jiangsu province, China, and during March 2001 in Yichang (30°36′N, 111°12′E), Hubei province, China.

Mollusk Collection and Rearing

***R. leonina* (Figure 1):** One living animal was collected from Zhongshanling, 2nd May 2000, two ones from Yichang on 30th Sept. 2000 and 49 (both adults and juveniles) from the same site in Yichang on 19th March 2001, respectively. In the meantime, the predatory behavior of *R. leonina* was observed both in the field (at Nanjing and Yichang) and in the laboratory. The *R. leonina* slugs used in the present experiments and non-experiment observation were more than 52 slugs from the field and their offspring cultured in the laboratory. Hatchlings were separated from their parents and were raised

Figure 4. Empty shells of prey. Upper row and left five of lower row: *Trichobradybaena submissa*; right four of lower row: *Opeas arctispirale*.

together in the same container as the parents' (see below), with fresh eggs of *Trichobradybaena submissa* (Deshayes, 1873; generic position see Wu & Guo, 2003) as their daily food and with the empty snail egg shell not removed in this period. When they reached about 10 mm, they were separated and two non-experiment slugs were randomly picked out and raised together in one keeping container. All the slugs used in the experiments (see below) were adult individuals, whose maturity were proven by the fact that they began laying eggs. Each adult predatory slug used in the experiments and in non-experiment observation was given a unique code such as A, E2 or Q4.

Tested preys: Plenty of living slugs (both adults and juveniles) of Limacidae, *Lehmannia valentiana* (Férussac, 1823) and *Limax* (*Limacus*) *flavus* (Linnaeus, 1858), slugs of Philomycidae, *Meghimatium bilineatum*, snails of Bradybaenidae, *Bradybaena similaris* (Rang, 1831), *Acusta ravida* (Benson, 1842), and *Trichobradybaena submissa*, and snails (both adults and juveniles) of Subulinidae, *Opeas arctispirale* (Gredler, 1887), were collected in Yichang for this purpose. The snails not cooccurring with *R. leonina*: both adults and juveniles of *Cathaica fasciola* (Draparnaud, 1801) (Bradybaenidae), were collected in the outskirts of Beijing; *Helix* (*Cryptomphalus*) *aspersa* (O. F. Müller,) (Helicidae) and *Achatina fulica* (Bowdich) (Achatinidae), were taken from laboratory cultures. All above mentioned slugs and snails as well as their offspring, raised and used in the experiments, were kept in the laboratory located in Beijing. The eggs of *B. similaris, A. ravida,* and *T. submissa,* laid in the keeping containers in the laboratory, were available all the time during the experiments.

Food for tested non *R. leonina* slugs and prey snails: Snail's biscuit made of hen eggshell 6%, soybean 27%, food-pellets for egg-laying hens 16%, maize 50%, Vitamin C 1%, finely smashed and well mixed with an appropriate amount of water, molded into blocks of 1 cm^3, dried in a microwave oven. The biscuit was soaked with water for 1 min before feeding. Lettuce was offered and changed every two days, and the keeping containers were cleaned frequently.

Keeping containers for *R. leonina*: Transparent polythene boxes (123 mm × 80 mm × 50 mm), a 0.5 mm space between the lid and the base ensuring the humidity and necessary air supply. A 10-mm layer of wet vermiculite was evenly spread over the bottom of the box, and every ten days some water was added to the box to keep the humidity stable. The relative humidity in the keeping containers was kept at 86% ± 5%. The different-sized individuals of *T. submissa,* as well as their newly laid eggs (which were laid in other containers and/or laid by the food *T. submissa* put into the keeping container for *R. leonina*) were supplied as slugs' daily food.

Design of Experiment on Prey Size Choice

Fifteen predatory slugs (from adults collected in Yichang in March 2001 and their mature offspring) were studied

Figure 5. Empty shells of prey. Upper row: *Cathaica fasciola*; left two of middle row: *Acusta ravida*; right three of middle row: *Bradybaena similaris*; lower row: *Trichobradybaena submissa.*

to test whether or not their choice of prey snails depended upon the snails' size, shell shape or the different degree of maturity, from March 28th to May 11th, 2001. All the fifteen *R. leonina* individuals, which in size (estimated by the weight) included the smallest and the largest slug (Figure 2), were tested for the full period. In each experimental system (treatment), one predatory slug was placed into a keeping container together with six numbered *T. submissa* individuals, whose size and morphology were measured and the degree of maturity was recorded. If *T. submissa* laid eggs during the experimental period, the laid eggs were quickly moved away. After a kill by the slug, the empty snail shell was promptly removed and a healthy snail of similar size and maturity, numbered and measured, was added. During the experiment, the fifteen tested individuals' weights were measured every week.

The laboratory-kept predatory slugs were grouped into two groups according to their weights, using K-means Cluster Analysis. The slugs in Group 1 with the weight ranging from 0.18 to 0.55 g were represented by the final cluster center 0.31, and those of weights ranging from 0.63 to 1.02 g in Group 2 were represented by the final cluster center 0.80 (Table 1). Using the same method, all the tested snails of *T. submissa* were grouped into three groups by shell height, shell diameter, and relative apertural area approximately represented by the product of apertural length and apertural width (Wu & Chen, 1998). Then, if a snail was preyed on during the experiment period, its shell parameters and the degree of maturity were recorded as "1"; otherwise they were recorded as "0" (sum of the records see Table 2). Npar Analysis was employed to detect if any of these factors affected the slugs' predation.

Design of Experiment on Egg Choice

A food choice test of three kinds of snail eggs, to detect whether or not *R. leonina* prefers specific snail eggs (*T. submissa, B. similaris* and/or *A. ravida*), was designed and the experimental set was depicted as Figure 3. This experiment lasted for ten days from April 18th to 27th, 2001. In each of thirteen tested predatory slugs (E1–E13, slugs from adults collected in Yichang in March 2001 and

Figure 6. Shells of juvenile *Achatina fulica*, preyed upon by *R. leonina*.

their mature offspring cultured in the laboratory), 10 newly laid eggs each of *T. submissa, B. similaris,* and *A. ravida* were added to pits A, B and C respectively (each pit was dug by 0.5 cm depth and partially separated by two pieces of thin glass (40 mm × 40 mm, thickness 0.5 mm); the distance between the centers of the two adjacent pits was 30 mm). In eight controls (C1–C8): each pit of C1–C3 contained 10 newly laid eggs of *T. submissa,* each pit of C4–C6 contained 10 newly laid eggs of *B. similaris,* and each pit of C7–C8 contained 10 newly laid eggs of *A. ravida.* During the experiment the tested slugs received no additional food. The number of eggs consumed was recorded at the end of the experiment.

Table 3

The predation by *R. leonina* in the field and/or in the laboratory. +: offered and preyed upon in the laboratory; ++: predation was observed in the field; −: offered but not preyed upon in the laboratory; ?: not tested in the present experiments.

Species	Eggs	Hatchlings	Elder juveniles	Adults
Acusta ravida	+	+	+	+
B. similaris	+	+	+	+, ++
T. submissa	+	+	+	+
C. fasciola	?	+	+	+
H. (C.) aspersa	?	+	+	−
O. arctispirale	?	?	+	+
Achatina fulica	?	+	+	?
M. bilineatum	−	−	−	−
Limax (Limacus) favus	−	−	−	−
Lehmannia valentiana	−	−	−	−

Method of Weighing, Measuring and Data Analysis

The weight of slugs was measured with a calibrated digital electronic balance (accuracy ±1 mg, EX-200A, Mehcuhy), in the experiment on prey size choice. The length measurements of *T. submissa* were made with a calibrated electronic digital display caliper (accuracy ±0.01 mm). The maximum diameter of *R. leonina* eggs was obtained from digital photographs and measured by Photoshop 5.0. Statistical calculations were performed using SPSS for Windows 8.0.0 (SPSS Inc, 1989–1997, Standard Version). Bivariate correlation (2-tailed Pearson Correlation), non-parametric tests for several related samples (Kendall's W Test and Friedman Test) and K-means Cluster Analysis using for grouping numerical characters were employed.

RESULTS

Morphology of *R. leonina*

The weight of the adult slug ranges from 0.18 g to 1.02 g (Figure 2). The length is shorter than 35 mm when inactive. Its body contracts inconspicuously when preserved in 70% ethanol. The body color is light grayish brown to dark gray, sometimes reddishly tinted, and the color fades in ethanol solution. It has numerous discontinuous short black longitudinal striations, which are shortened and turned into elliptic spots when the slug

Figure 7. *R. leonina* preying on a mature *T. submissa.*

contracts, distributed on its dorsal side. The sole of the animal is uniformly light reddish brown. The epidermis excretes a small amount of very sticky mucus. The optic tentacles are short and black, the lower pair of tentacles is somewhat shorter, lead-colored, bifurcate, and distally tapering when fully stretched (Figure 1).

Habitat

R. leonina is distributed from the middle to lower reaches of the Yangtze River, and is only known in Nanjing, Yichang and Shaoguan from our collection. It lives usually at foothills and adjoining land, sometimes also in city gardens. In field observation during the dry season in May 2000 at Nanjing, *R. leonina* inactively rested between the surface of sandy loam and thick litter layer, with co-occurring land mollusk species *Cyclophorus* sp. and *A. ravida* which were also inactive. In September 2000 and March 2001 at Yichang, in the fairly humid environment, this species actively moved on the litter-free laterite, with co-occurring mollusks *L. valentiana, L.* (*Limacus*) *flavus, M. bilineatum, B. similaris, A. ravida* and *O. arctispirale.* It prefers conditions of high humidity and shade, and usually rests on cool and smooth surfaces, such as on the underside of earth-free stones, bricks, and even on plastic pieces. Sometimes it retreats within the crevices of moist clods or within earth tunnels produced by other organisms. In the field, they are known to be active in temperature ranges from 10.5°C (lowest temperature in May) to 35.5°C (highest temperature in May) in Nanjing, and from 4.0°C (lowest temperature in March) to 35.0°C (highest temperature in March or October) in Yichang.

Predation

In the field, several times one to three *R. leonina* were observed around an egg clutch of *M. bilineatum.* Some egg clutches with *R. leonina* resting nearby became milky and irregular in shape, and well distinguished from those in normal condition. However, we never observed *R. leonina* feeding on the eggs of *M. bilineatum* in the field or in the laboratory. In the laboratory, *R. leonina* was observed to prey on animals of *O. arctispirale, C. fasciola, A. fulica* and *H.* (*C.*) *aspersa,* and animals and eggs of *B. similaris, A. ravida* and *T. submissa* Deshayes (Figures 4–6; Table 3). None of the slugs tested were attacked or preyed upon. When preying on snails, they always attacked the body through the shell aperture. The prey snail contracted faster than normal, and secreted a large amount of foam or mucus. They then became quiescent and seemed to be insensitive to the predation by *R. leo-*

Figure 8. *R. leonina,* preying on a hatchling of *A. fulica.*

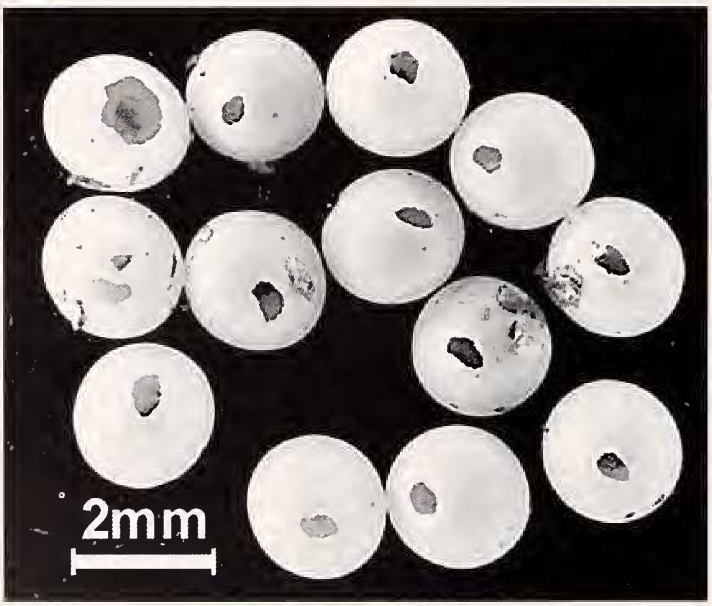

Figure 9. Empty egg shells of *T. submissa,* preyed upon by *R. leonina.*

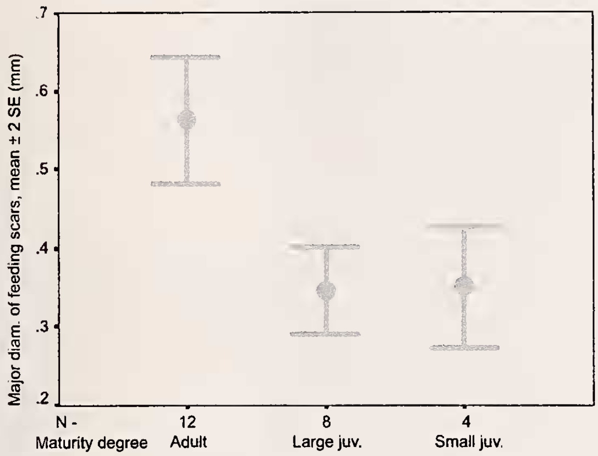

Figure 10. Mean major diameter ± SE (mm) of feeding scars left on the eggshells of *T. submissa* made by *R. leonina* of different maturity degree.

nina. Two methods of feeding were used by this slug, inserting its head into the aperture (Figure 7), or just protruding the proboscis (termed 'suction trunk' by Heude, 1884) into the aperture (Figure 8), depending upon the aperture size of the prey.

The statistical results shown in Table 2 indicated that smaller slugs (from Group 1) preferred mature snails, which were generally those with a larger shell diameter and larger aperture (asymptotic significance <0.05), to juveniles. For larger slugs (from Group 2), no preference was detected (Table 2).

When *R. leonina* fed on snail eggs, it always kept a pose of curving its head and 'neck' in order to hold and fasten the egg, and bit into the egg a tiny hole, or feeding scar, which usually showed the shape of an elongated ellipse, a circle or rarely amorphous shapes. The edge of the hole was smooth or somewhat serrate (Figure 9). The laboratory observation on non-experiment predatory slugs showed: if they found eggs in the egg-laying pits dug by *T. submissa,* they sometimes stayed in the pits until all inside eggs had been consumed; the holes produced by the adults and the juveniles could be distinguished by the major diameter range, as for older or

Figure 11. *R. leonina* in copulation.

Table 4

R. leonina's preference for the eggs laid by three species. In experimental systems (treatments) E1–E13, pit A contained 10 *T. submissa* eggs, pit B contained 10 *B. similaris* eggs, and pit C contained 10 *A. ravida* eggs. In controls, each pit contained 10 eggs—in controls C1–3, pits A, B and C with *T. submissa* eggs; in controls C4–6, pits A, B and C with *B. similaris* eggs; incontrols C7 and 8, pits A, B and C with *A. ravida* eggs.

	Sum of consumed eggs in Pit A	Sum of consumed eggs in Pit B	Sum of consumed eggs in Pit C
E1–E13	11	7	28
C1–C3	8	8	7
C4–C6	13	6	6
C7, C8	8	3	10

younger juveniles the holes were smaller (Figure 10). The major diameter of feeding holes made by a mature individual of *R. leonina* ranged from 0.41 mm to 0.62 mm, and those made by elder or younger juveniles ranged from 0.24 mm to 0.47 mm.

R. leonina showed a significantly different preference for eggs laid by *T. submissa, B. similaris* and *A. ravida* (Table 4, Test for several related samples, Asymp. Sig. = 0.010; in controls, Asymp. Sig. = 0.267). The preference rank from high to low is: eggs of *A. ravida* > eggs of *T. submissa* > eggs of *B. similaris*.

Reproduction

Mature individuals: The mature slugs ranged from 0.18 g to 1.02 g. In the laboratory, only a few mating cases were observed in time. A copulating pair of *R. leonina* could be instantly distinguished from their connecting the right sides of the anterior parts (Figure 11).

Prior to egg laying, the slug dug a hole in the vermiculite layer. The hole was slightly broader than the slug itself and of ca. 5–10 mm depth. Then the animal inserted its anterior body into the hole and began to lay eggs. It seldom laid eggs on the surface of the vermiculite layer (Figure 12). The eggs of *R. leonina* were translucent, light smoke-blue to light pink, spherical or ellipsoidal (Figures 12, 13). In the field, the eggs of *R. leonina* could not be easily distinguished from those laid by *L. valentiana* (Figure 14). In the laboratory, recorded egg laying was observed 8 times in 5 different individuals, i.e., predatory

Figure 12. *R. leonina* laying eggs; eggs pink.

Figure 13. Eggs of *R. leonina,* eggs normal smoke-blue.

Figure 14. Eggs of *Lehmannia valentiana,* similar to those of *R. leonina.*

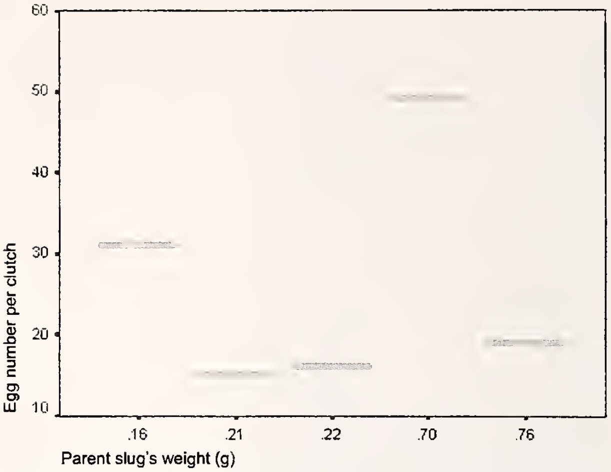

Figure 15. The relationship of parent *R. leonina* slug's weight (g) and the egg number per clutch.

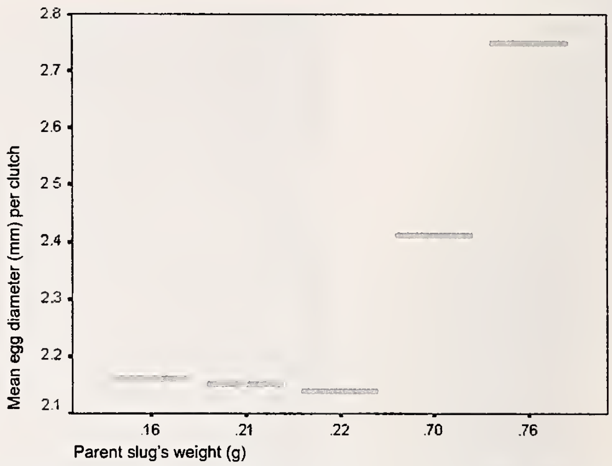

Figure 16. The relationship of parent *R. leonina* slug's weight (g) and the mean egg diameter (mm).

slug A laid 4 clutches during the experiment on prey size choice and during the daily culture. Most egg laying data from the slug daily culture were not recorded in order to avoid influencing the cultured slug maintenance. The predatory slug A laid its 4 clutches in the intervals of 6, 6 and 4 days respectively. Each one of the 8 clutches was made up of 10–49 eggs, the large diameter of the eggs ranged from 1.88 mm to 3.09 mm (mean 2.30 mm). The weight of the parent predatory slugs showed no correlation to the numbers of eggs of each clutch (Figure 15; 2-tailed Pearson Correlation, sig. = 0.508), but showed a positive correlation to the eggs' diameters (Figure 16; 2-tailed Pearson Correlation, sig. = 0.025).

Hatching

The embryos were visible by the naked eye when the eggs started to develop. In the condition of 17.5–23.5°C in the laboratory, it took 25–29 days for the eggs to hatch (Figure 17). In the first 1–3 days the hatchlings remained inside the egg-laying pit before they moved out of the pit and searched for food. Like their parents, the juveniles fed on calcareous snail eggs, hatchlings of snails and never fed on herbivorous slug's eggs.

DISCUSSION

Prey preference of the predatory land mollusks is always an important topic (Cowie, 2001). The present result showed that smaller individuals of the predatory slugs were particularly selective with respect to shell shape and size of prey, although larger individuals showed no preference. The Indian carnivorous shelled snail *Gulella bicolor* preferred the snails *Opeas gracile* of the size close to themselves (Raut & Shahbabu, 1986). Under natural conditions, compared with *Incillaria* sp. (sensu Kurozumi, 1985), *R. leonina* shows a more narrow prey range, i.e., a less developed species preference. The former species was observed to consume the snails and eggs of helicoids such as *Satsuma mercatoria* (Camaenidae), *Bradybaena circulus* and *Aegista elegantissima* (Bradybaenidae), the animals and eggs of prosobranch snails such as *Georissa fukudai* (Hydrocenidae) and *Cyclophorus turgidus* (Cyclophoridae), and perhaps *Achatina fulica* (only inferred from the feeding scars left on the egg shells) (Kurozumi, 1985). For *R. leonina,* only species without operculum, such as bradybaenids, and perhaps subulinids (not directly observed in the field, only inferred from subulinids co-occurred in the habitats being predated in the laboratory).

The most interesting result of the present study is the prey preference of *R. leonina,* showed by the experiment based on the eggs of three species *T. submissa, B. similaris* and *A. ravida.* However, limited by the food material for *R. leonina,* using eggs of *T. submissa* as the daily food of *R. leonina* might have influenced the results of the egg choice experiments: The slugs might have been "saturated" with *T. submissa* eggs, and preferred eggs of the other two snail species for a change (Heike Reise, reviewing comments, 2004). This consideration raised the subsequent work which will be of great interest and necessary.

In addition to the general interest in the natural history of predatory land mollusks, the idea for this study arose partly from the desire of choosing some 'beneficial' species with the purpose of controlling other harmful terrestrial snails such as the introduced *A. fulica.* For instance in Asia, *Gulella bicolor* (Hutton) that can prey on *A. fulica,* had been introduced into South Andamans in order to control the giant African snail before 1975 (Raut & Shahbabu, 1986). The present field observations show that *R. leonina* can occupy open habitats, such as at Yichang, and dry environments, such as at Nanjing. The

Figure 17. Hatchlings of *R. leonina*, making for the eggs of *T. submissa*; notice some eggs with regular feeding scars left on the egg shells.

present direct observations have enriched our knowledge of the habitat of this group, adding to data for related species described by Kurozumi (1985). The use of similar habitats by the dubious 'philomycid' (*Incillaria* sp., sensu Kurozumi, 1985) and *A. fulica* implies that such species may be considered as a bio-control agent against *A. fulica* (Kurozumi, 1985). However, the present experiments challenge such consideration promptly, and at least two obvious problems exist. First, the experiments showed clearly that *R. leonina* preys on a wide variety of snail species and eggs. Although the experiments showed the preference for the eggs of agriculture pest snail *A. ravida*, people know almost nothing about whether or not the predatory slugs will show a stronger preference to other snails untested in the present study, whether the preference is of high plasticity which might be revealed when adding the species of the tested snails, and so on. Second, presuming we know this predatory slug well in the laboratory, what the situation will be when the slugs are in the field? It is well known that usually the laboratory result is too weak to predict the relevant situation in the field. The well known examples here are the East African carnivorous snails *Gonaxis kibweziensis* (Smith) and *G. quadrilateralis* (Preston) (Streptaxidae), and the rosy wolf snail *Euglandina rosea* (Férussac) (Spiraxidae), once the introduced 'bio-control agents' and eventually known as the dangerous invasive species, which in Hawaii and other places have been causing ecological calamities (Cowie, 2001). So the risk of their possible impact on the native biota should be adequately assessed before any consideration can be made on using them as so-called 'beneficial bio-control agent'. The effort of using predatory non-marine mollusks as bio-control agents, as well as the direct damage and potential danger, has been well reviewed by Cowie (2001). Because very little biological research has ever been carried out upon this species, and much more remains to be done prior to making any conclusion, especially in relation to biocontrol practices. Besides the biology of *R. leonina*, the impact on the population dynamics of different landsnail species should be emphasized in further work.

Acknowledgments. We are grateful to Dr Rüdiger Bieler (Field Museum of Natural History, USA), Dr Beata Pokryszko (Museum of Natural History, Wroclaw University, Poland), Dr José W. Thomé (Laboratório de Malacologia PUCRS, Brazil), Dr Robert H. Cowie (Hawaii University, USA) and an anonymous referee, for their good suggestions to relevant work. Great thanks go to Dr Tim Pearce and Dr Heike Reise for reviewing the manuscript and providing critical comments. The work could not have been performed without having been sponsored by the Laboratory of Biocontrol Resources, Ministry of Agriculture, China

(LOBOR-00-04), the grants from the Natural Science Foundation of China (NSFC, No. 30100017).

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